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10/529363  
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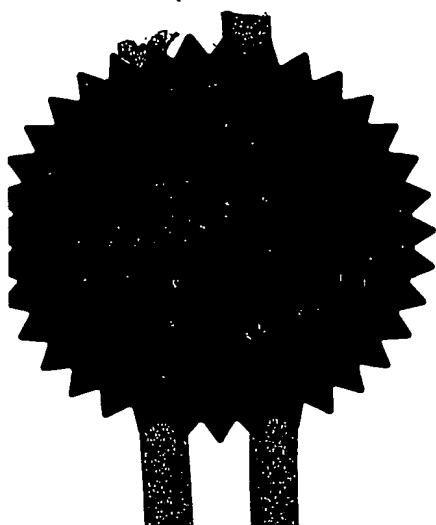
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P01/7700 0.00-0222397.2

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1. Your reference

2. Patent application number

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3. Full name, address and postcode of the or of each applicant (underline all surnames)

Arrayjet Limited  
Unit 5, McSence Business Enterprise Park  
32 Sycamore Road  
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08103780002

Patents ADP number (if you know it)

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

Method and apparatus for substrate handling and printing

5. Name of your agent (if you have one)

Kennedy's Patent Agency Limited

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

Floor 5, Queens House  
29 St Vincent Place  
GLASGOW  
G1 2DT

Patents ADP number (if you know it)

08058240002

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Country

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7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:

Yes

- a) any applicant named in part 3 is not an inventor, or
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11. I/We request the grant of a patent on the basis of this application.

Signature  Kennedy

Date 27.09.02

12. Name and daytime telephone number of person to contact in the United Kingdom **Matthew Lincoln Tel: 0141 226 6826**

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1 Method and apparatus for substrate handling and printing

2

3 The present invention relates to the field of printing,  
4 and in particular to the printing of large number of  
5 substrates.

6

7 Ink jet printheads can be used to position spots of  
8 liquids, for example biological samples, on substrates  
9 such as glass slides. An important application of this  
10 technique is the manufacture of DNA microarrays.

11

12 When manufacturing a microarray, it is normally required  
13 to print one, two, three or more spots of each liquid  
14 onto each of a large number (tens to hundreds) of  
15 substrates. Typically, there will be a very large number  
16 (hundreds to tens of thousands) of different liquids to  
17 be printed onto the substrates, so the printing process  
18 may be lengthy.

19

20 The cleaning of the printhead before the introduction of  
21 the next set of liquids takes time, and therefore the  
22 once a set of liquids has been introduced into the

1 printhead, they should be printed onto all the slides  
2 before another set of liquids is loaded.

3  
4 Patent application WO 02/11889 discloses a method whereby  
5 an ink jet printhead having multiple chambers, each  
6 associated with a nozzle, can be used to print multiple  
7 different liquids at the same time. The printing can be  
8 carried out without cross-contamination between the  
9 liquids, despite the fact that the chambers are connected  
10 by one or more manifolds internal to the printhead. The  
11 liquids are introduced via contiguous groups of nozzles  
12 into the associated chambers and printed before they have  
13 time to mix by diffusion. Handling multiple liquids  
14 therefore offers the possibility of reducing the time  
15 taken to do the considerable amount of printing required  
16 in the production of DNA microarrays.

17  
18 However, if a large number of slides is to be printed,  
19 their area is too large to allow them to be arranged in a  
20 plane for easy access during printing. It is therefore  
21 only practical to arrange smaller groups of the slides  
22 for printing. Since the slides do not occupy much  
23 volume, it is convenient to store the slides in a  
24 multilayer stack. However, the transfer into and out of  
25 storage inevitably occupies some time, conflicting with  
26 the need to minimise manufacturing time.

27  
28 It would therefore be desirable to provide a method and  
29 apparatus for handling and printing substrates that  
30 obviated or at least mitigated some of the drawbacks of  
31 conventional systems.

32

1 It is one aim of an aspect of the invention to provide a  
2 method for loading and unloading substrates to printing  
3 apparatus in an efficient and rapid manner.

4

5 It is a second aim of an aspect of the invention to  
6 provide apparatus for loading and unloading substrates to  
7 printing apparatus in an efficient and rapid manner.

8

9 Further aims and objects of the invention will become  
10 apparent from a reading of the description.

11

12 According to a first aspect of the invention, there is  
13 provided apparatus for transferring substrates to and  
14 from a printer, comprising:

- 15 - a first storage unit for storing substrates prior to a  
16 printing operation, the first storage unit having a  
17 plurality of vertically stacked substrate supports;
- 18 - a platen for receiving a substrate from said first  
19 storage unit, aligning the substrate with a printhead  
20 prior to a printing operation, and displacing the  
21 substrate subsequent to a printing operation to an  
22 unloading position;
- 23 - a second storage unit for storing substrates subsequent  
24 to said printing operation, the second storage unit  
25 having a plurality of vertically stacked substrate  
26 supports;
- 27 - wherein the first and second storage units are movable  
28 vertically with respect to the platen, and in use,  
29 relative vertical movement of the first storage unit  
30 and the platen transfers a substrate from the supports  
31 of the first storage unit to the platen, and relative  
32 vertical movement of the second storage unit and the

1 platen transfers a substrate from the platen to the  
2 supports of the second storage unit.

3

4 Preferably, the vertically stacked substrate supports of  
5 the first and second storage units are arranged to  
6 support substrate-handling trays for holding a plurality  
7 of substrates.

8

9 Preferably, the platen receives a substrate-handling tray  
10 from the first storage unit, the substrate being held on  
11 said substrate handling tray.

12

13 The substrate handling tray may extend lengthways across  
14 the width of the platen, the length of the tray being  
15 greater than the width of the platen.

16

17 Preferably, the first and second storage units are frames  
18 defining an interior cavity, into which the platen  
19 extends.

20

21 According to a second aspect of the invention, there is  
22 provided a method for transferring substrates to and from  
23 a printer, comprising the steps of:

- 24 - imparting relative vertical movement between a first  
25 storage unit for storing substrates and a platen, the  
26 first storage unit having a plurality of vertically  
27 stacked substrate supports, thereby transferring a  
28 substrate from the supports of the first storage unit  
29 to the platen;  
30 - aligning the substrate with a printhead;  
31 - printing on the substrate;  
32 - displacing the substrate to an unloading position;

1 - imparting relative vertical movement between a second  
2 storage unit for storing substrates and the platen, the  
3 second storage unit having a plurality of vertically  
4 stacked substrate supports, thereby transferring a  
5 substrate from the platen to the supports of the second  
6 storage unit.

7  
8 According to a third aspect of the invention, there is  
9 provided a method for printing substrates on a platen,  
10 the method comprising the steps of:  
11 - printing a substrate by imparting linear movement to  
12 the printhead, thereby causing the printhead to  
13 traverse the substrate in a first direction, whilst  
14 simultaneously transferring a further substrate between  
15 the platen and a substrate storage unit;  
16 - aligning the second substrate tray with the printhead,  
17 whilst reversing the direction of motion of the  
18 printhead;  
19 - printing the substrates held on a second substrate tray  
20 by imparting linear movement to the printhead, thereby  
21 causing the printhead to traverse the substrates in a  
22 second direction opposite to the first.

23  
24 Preferably, the transfer of a substrate between the  
25 platen and the substrate storage unit is carried out by  
26 imparting relative vertical movement between a substrate  
27 storage unit and the platen, the storage unit having a  
28 plurality of vertically stacked substrate supports.

29  
30 According to a fourth aspect of the invention, there is  
31 provided a method for printing substrates on a platen,  
32 the method comprising the steps of:



- 1 - printing a substrate by imparting linear movement to  
2 the printhead, thereby causing the printhead to  
3 traverse the substrate in a first direction;  
4 - transferring a further substrate between the platen and  
5 a substrate storage unit;  
6 - aligning the further substrate with the printhead,  
7 whilst reversing the direction of motion of the  
8 printhead;  
9 - printing the substrates held on a second substrate tray  
10 by imparting linear movement to the printhead, thereby  
11 causing the printhead to traverse the substrates in a  
12 second direction opposite to the first.

13  
14 According to a fifth aspect of the invention, there is  
15 provided a method for printing substrates on a platen,  
16 the method comprising the steps of:

- 17 - printing a substrate by imparting linear movement to  
18 the printhead, thereby causing the printhead to  
19 traverse the substrate in a first direction, whilst  
20 simultaneously transferring a further substrate between  
21 the platen and a substrate storage unit;  
22 - aligning the second substrate tray with the printhead;  
23 - reversing the direction of motion of the printhead;  
24 - printing the substrates held on a second substrate tray  
25 by imparting linear movement to the printhead, thereby  
26 causing the printhead to traverse the substrates in a  
27 second direction opposite to the first.

28  
29 Preferably, the steps of the method are repeated.

30

31 There will now be described, by way of example only,  
32 various embodiments of the invention with reference to  
33 the following drawings, of which:

1  
2 Figure 1 is a plan view of apparatus according to an  
3 embodiment of the invention;

4  
5 Figure 2 is a front view of the apparatus of Figure  
6 1;

7  
8 Figure 3 is a side view of the apparatus of Figure  
9 1.

10  
11 Figure 4 shows a side view of the apparatus and a  
12 table useful for explaining a method in accordance  
13 with an embodiment of the invention.

14  
15 Figure 5 shows a table useful for explaining a  
16 method in accordance with an alternative embodiment  
17 of the invention.

18  
19 Referring firstly to Figures 1 and 2, the apparatus  
20 generally depicted at 10 includes a platen 12, four cages  
21 13a to 13d, and a linear rail 14. Each cage is a  
22 rectangular metal frame 15 having a series of vertically  
23 stacked substrate supports in the form of inwardly  
24 protruding ledges 16. The cages are shaped to receive a  
25 number of slide trays 17, each slide tray holding a  
26 linear array of slides to be printed. Each slide tray 17  
27 is oriented lengthways across the width of the platen 12,  
28 and the length of the trays is greater than the width of  
29 the platen. The platen 12 is therefore able to extend  
30 into a central cavity defined by the frame of the cage.

31  
32 The platen 12 has four positions for receiving slide  
33 trays. Above one of the positions is a linear rail 14

1 along which the printhead 19 can be moved in a  
2 reciprocating motion following a trapezoidal velocity  
3 profile. The acceleration and deceleration associated  
4 with the changing of direction of the printhead at each  
5 end occurs beyond the end of the trays. The printhead  
6 axis is positioned with two cages 13 on either side. A  
7 suitable printhead is the XaarJet XJ126R.

8  
9 The arrangement for the slides within a tray is a linear  
10 array of, say, twenty five slides 18 with their short  
11 edges parallel to the long axis of the trays and the long  
12 edges of adjacent slides facing one another. This  
13 minimises the time occupied travelling over each slide.  
14 A convenient pitch for the slides is 27 mm, which allows  
15 space for mechanisms to hold the slides, and fits in with  
16 the possibility of using two or more printheads, line  
17 astern. A printhead such as the XaarJet XJ126R can be  
18 set at a pitch of 54 mm, which works well with the 9 mm  
19 pitch of the well-plates from which the liquids are  
20 usually obtained.

21  
22 As shown in Figure 2 ledges 16 of the cages above the  
23 platen 12 are filled with trays 17 (all but one shown in  
24 dotted lines for clarity), while the ledges below are  
25 empty. The cage is shown in a position where it has  
26 moved downwards, so that the tray is brought into contact  
27 with the platen. A slight further downward movement of  
28 the cage causes the tray to come to rest on the platen,  
29 freeing the trays from the ledges of the cage on which it  
30 was resting and depositing it onto the platen. A  
31 subsequent fore-aft movement of the platen will carry the  
32 tray to a position outside the frame of the cage.  
33

1 Figure 3 shows the four cages 13a to 13d from a side  
2 view. Cages 13a and 13c are loaded with slide trays (not  
3 shown), and are positioned above the platen. In use,  
4 these upper cages will descend in stages from the high  
5 positions, depositing trays onto the platen in readiness  
6 for printing. In contrast, cages 13b and 13d are empty  
7 of trays, and are initially located in low positions  
8 below the platen. Cages 13b and 13d ascend from these  
9 low positions, unloading trays from the platen after  
10 printing.

11  
12 The platen 12 is shown in one of its four possible  
13 positions, in which it spans four of seven equally sized  
14 regions of space. The other positions are shown by  
15 dotted lines 21. The two extreme positions are outside  
16 of the boundary of the cages 13.

17  
18 The operation of the apparatus will now be described with  
19 reference to Figure 4. The Figure shows the apparatus  
20 from a side view, and a table useful for understanding  
21 the handling and printing process.

22  
23 Each row of the table represents a different time  
24 interval during the process. Time passes from the top of  
25 the table to the bottom. The first four rows represent a  
26 start-up sequence for loading and printing the first  
27 trays, and the bottom four rows represent an end sequence  
28 for dealing with the last trays. The middle four rows  
29 are repeated for as many iterations as is necessary for  
30 printing the entire batch of slides.

31  
32 Each column of the table corresponds to a possible  
33 position of the platen. The platen occupies four

1 adjacent positions within the seven. The actual position  
2 of the platen at any time is indicated by the shaded  
3 portions of the table.

4  
5 The apparatus is initially set up as follows: the two  
6 cages 13a, 13c are in their uppermost positions, fully  
7 occupied by trays of slides; cages 13b, 13d are in their  
8 lowest positions, empty. The platen is initially empty.

9  
10 First a startup sequence is performed, as represented by  
11 rows R1 to R4 of Figure 4:

12  
13 The platen is positioned as illustrated, occupying the  
14 third to sixth of the seven regions (counting from the  
15 left). The first tray is loaded onto the platen by a  
16 downward movement of the right-most cage, cage 13a. As  
17 described above, the downward movement of the cage causes  
18 the tray to come to rest on the platen, freeing the tray  
19 from the ledges of cage 13a and depositing it onto the  
20 platen. This action is represented by the word 'load' in  
21 the table, underneath the cage in question.

22  
23 The platen then moves one pitch to the right placing the  
24 tray outside the frame and ledges of cage 13a. A second  
25 tray is loaded by cage 13a to a platen position adjacent  
26 to the first tray.

27  
28 The platen then moves three pitches to the left, so that  
29 it occupies the first to fourth positions. Next, the  
30 printhead performs its first movement, printing the  
31 slides located on the first tray (now located under the  
32 printhead rail). This action is represented by the word

11

1 'print' underneath the printhead in the table of Figure 4  
2 at row R3.

3

4 When the printhead has passed the end of the slide tray,  
5 the printhead slows down and changes direction. While  
6 the printhead is turning round, the platen moves one  
7 pitch to the right. The printhead now prints the second  
8 of the trays, while moving in the reverse direction.  
9 Simultaneously, while the printhead is moving but the  
10 platen is stationary, the cage 13c loads a third tray.  
11 At the same time, cage 13b unloads the first tray that  
12 was printed. This unloading action is effectively the  
13 reverse of the loading action. The cage 13c surrounds  
14 the tray as it rests on the platen, and the ledges are  
15 located underneath the ends of the tray. The cage 13b  
16 moves upwards, so that the ledges are brought into  
17 contact with the tray, and then lift the tray from the  
18 platen. This unloading action is represented in the  
19 table of Figure 4 is 'unload'.

20

21 The platen moves one pitch to the right, completing the  
22 start-up sequence, and the system enters a central  
23 sequence that is repeated as often as is appropriate for  
24 the number of trays in the machine.

25

26 The central sequence follows the same principle. Cages  
27 13 load and unload trays during printing and when the  
28 platen 12 is stationary. The platen moves while the  
29 printhead is reversing direction. The central sequence  
30 shown, consists of four stages, represented by rows R5 to  
31 R8. The apparatus first loads two trays from cages 13a  
32 and 13c, unloads one tray onto cage 13b, and prints the  
33 tray that is aligned with the printhead. The following

1 two steps respectively involve a print operation and the  
2 loading of a new tray from cage 13a, and print operation  
3 and an unloading action onto cage 13d. The central  
4 sequence therefore prints four trays in four traverses of  
5 the printhead. That is, the printhead is busy at every  
6 step of the process. The central sequence is repeated as  
7 many times as necessary, until the cages 13a and 13c are  
8 almost empty of trays.

9

10 Rows R9 to R12 represent an end sequence for handling the  
11 remaining trays on the platen 12. At R9, the final tray  
12 is loaded onto the platen from cage 13d, the penultimate  
13 tray is printed, and a tray is unloaded onto cage 13b.  
14 The next steps involves the printing of the final tray,  
15 and the subsequent unloading of the trays onto cage 13d.  
16

17 The whole of the above-described operation consists of a  
18 start-up sequence, a number  $n$  of repeats of the four-  
19 stage central sequence, and an end sequence. The  
20 operation results in the printing of a set of liquids  
21 held within the printhead onto all  $4(n+1)$  trays of slides  
22 in the machine. At the end of this operation the trays  
23 have been transferred, with reversal of order, from the  
24 two loading cages 13a, 13c to the two unloading cages  
25 13b, 13d. Cages 13a, 13b were initially in a raised  
26 position, but have now descended below the platen,  
27 emptying of trays. Cages 13b, 13d, initially below the  
28 platen, have ascended filling with trays.

29

30 It is notable that only four out of a total of  $4(n+2)$   
31 operations do not involve printing, so the printhead is  
32 kept busy with great efficiency, particularly if  $n$  is  
33 substantial.

1  
2 When the next set of liquids has been acquired by the  
3 printhead, the entire operation is applied in reverse,  
4 printing the new set of liquids onto slightly different  
5 positions on all the trays of slides. The load cages  
6 13a, 13c, which were moving downwards, have now become  
7 unload cages moving upwards, and vice versa. The scheme  
8 illustrated in the table of Figure 4 has the highly  
9 desirable property that every tray is printed with the  
10 printhead travelling in the same direction as with the  
11 previous set of liquids. This minimises errors due to  
12 the time of flight of the drops, as the shifts will in  
13 the same direction for all liquids printed onto a given  
14 slide. At the end of two complete operations, two sets  
15 of liquids have been printed onto all of the slides, and  
16 all the cages and trays are back in their original  
17 positions.

18  
19 Multiple sets of liquids are printed using the same  
20 overall operation, alternately in the order given in  
21 Figure 4 and in reverse. The positions on the slides of  
22 the sets of spots are shifted in the direction of  
23 printhead motion by applying different offsets to the  
24 triggering electronics each time the printhead performs a  
25 series of traverses. After a number of operations, the  
26 slides have been filled with spots along the line of  
27 travel of the printhead. During the next few operations,  
28 the four positions visited by the platen, while still  
29 equally spaced at the same pitch, are shifted slightly  
30 relative to the previous ones. This causes another row  
31 of spots to be printed on the slides. It is necessary  
32 for the entire assembly of four cages to occupy a  
33 slightly different position for each row of spots. As



1 printing of a large number of liquids proceeds, multiple  
2 rows of spots are produced on the slides. Their spacing  
3 in the direction of printhead travel is controlled by the  
4 timing of printhead triggering, and the spacing  
5 perpendicular to printhead motion is determined by the  
6 shifts in platen positions. Accuracy of spot positioning  
7 is guaranteed by the accuracy of these two motions and by  
8 the mechanism whereby trays stored on inaccurately  
9 manufactured cages are located precisely on the platen as  
10 they are loaded.

11

12 The sequence in the table of Figure 4 prints  $4(n+1)$  trays  
13 of slides. If the number of trays to be printed is even  
14 but not divisible by four, i.e.  $4n+2$ , the sequence shown  
15 in the table of Figure 5 can be used. This sequence  
16 appears to be slightly more efficient than that in the  
17 table of Figure 4, in that one fewer stage is required at  
18 start-up and at the end. However, as explained above, it  
19 is highly desirable to guarantee that individual slides  
20 are always printed with printhead motion in the same  
21 direction. The sequence of Figure 5 will require an  
22 extra traverse by the printhead at the outset, and at the  
23 end in order for the printhead motion to be consistent.

24

25 It is possible to extend these schemes to handle an odd  
26 number of trays or to handle the situation where the last  
27 tray is not filled with slides. Thus, any number of  
28 slides can be handled, not just a multiple of fifty.

29

30 Other schemes are possible, involving cages which load  
31 more than one tray at a time onto the platen; using two  
32 or more than four cages; using cages to store both  
33 unprinted and printed trays.

1  
2 A practical convenience of the proposed four-cage system  
3 is that at the outset the two cages closest to the front  
4 of the machine can be loaded with trays, and the platen  
5 used to transfer the contents of one of them to the rear  
6 of the machine as required to start the sequences of  
7 Figure 4.

8  
9 The present invention provides an efficient means of  
10 printing a large number of substrates, by providing a  
11 rapid means of storing, retrieving, printing and re-  
12 storing slides.

13  
14 The arrangement reduces the requirement for reloading the  
15 printhead with different liquids. The liquids are  
16 valuable and available in small quantities only. The  
17 loading of liquids into the printhead is inevitably  
18 wasteful in that only a proportion of each liquid is  
19 usefully printed. Ink jet printheads produce very small  
20 drops, so once liquids are introduced into the printhead,  
21 it can print a very large number of spots. The present  
22 invention utilises this characteristic of the printheads  
23 effectively.

24  
25 A further advantage of the invention arises from  
26 reciprocating the printhead motion using a one-  
27 dimensional transport, and mounting multiple trays on a  
28 platen which is capable of movement at right-angles to  
29 the printhead motion. The printhead traverses to print  
30 the tray which is in the appropriate position on the  
31 (stationary) platen; then the platen moves laterally  
32 while the printhead is turning round at the end of its  
33 stroke, bringing another tray of slides into position

1 underneath the axis of printhead motion. By the time the  
2 next printhead stroke takes place, the platen is again  
3 stationary. Accurate spot positioning is achieved in the  
4 direction of printhead travel by timing of the drop  
5 ejection, as disclosed in patent application WO 02/11889,  
6 and in the perpendicular direction by precise positioning  
7 of the platen.

8  
9 The invention therefore minimises the time during which  
10 the printhead is not printing.

11  
12 An additional advantage of this approach is that larger  
13 numbers of trays can be printed than those which fit on  
14 the platen; one or more cages can be used to store the  
15 trays when they are not being printed, to feed them onto  
16 the platen for printing and to remove them afterwards. A  
17 number of trays can be stored above each other on shelves  
18 in each cage; one or more cages can be moved vertically  
19 downwards so as to deposit the trays in turn onto the  
20 platen in preparation for printing. One or more other  
21 cages, moving vertically upwards, can remove them  
22 afterwards. The cages can perform these functions while  
23 the platen is stationary, during the printing stroke of  
24 the printhead. Thus the loading of trays onto the platen  
25 and unloading from it need not add to the time taken to  
26 print the overall number of slides in the machine; this  
27 scheme is equivalent in speed to a system using an  
28 impracticably large platen to hold all the trays.

29  
30 A further advantage of this approach is that the cages  
31 and their motion need not be precise: if the trays are  
32 equipped with location features which engage with  
33 matching features on the platen, the act of loading each

1 tray onto the platen ensures its accurate positioning  
2 with respect to the platen. The only parameters that  
3 need to be accurate are the printhead mounting, its  
4 motion, the platen's location features and its motion.  
5 Both of these motions are one-dimensional.

6  
7 It will be evident to the skilled reader that various  
8 changes could be made to the above-described embodiments  
9 within the scope of the invention. For example,  
10 different numbers of loading and unloading cages could be  
11 employed. In addition, one cage could unload trays, and  
12 could reload the same trays from the platen after  
13 printing. A further arrangement may utilise two cages  
14 that simultaneously unload or load two trays at different  
15 positions on the platen.

16  
17 Various modifications and improvements can be made within  
18 the scope of the invention herein intended.

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Figure 1

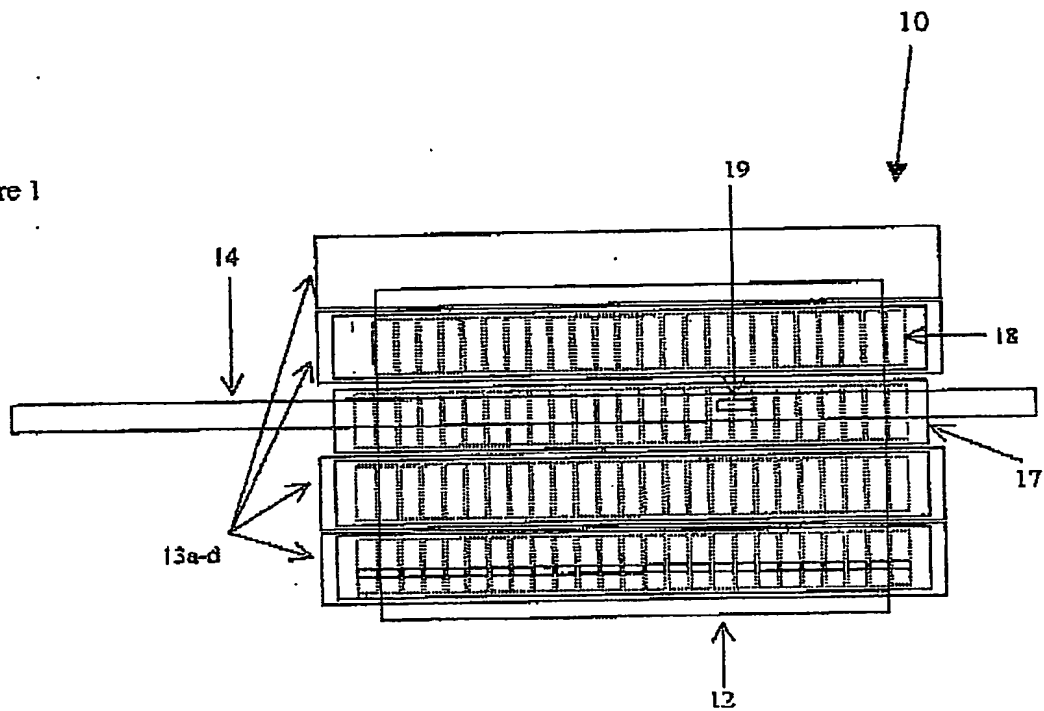
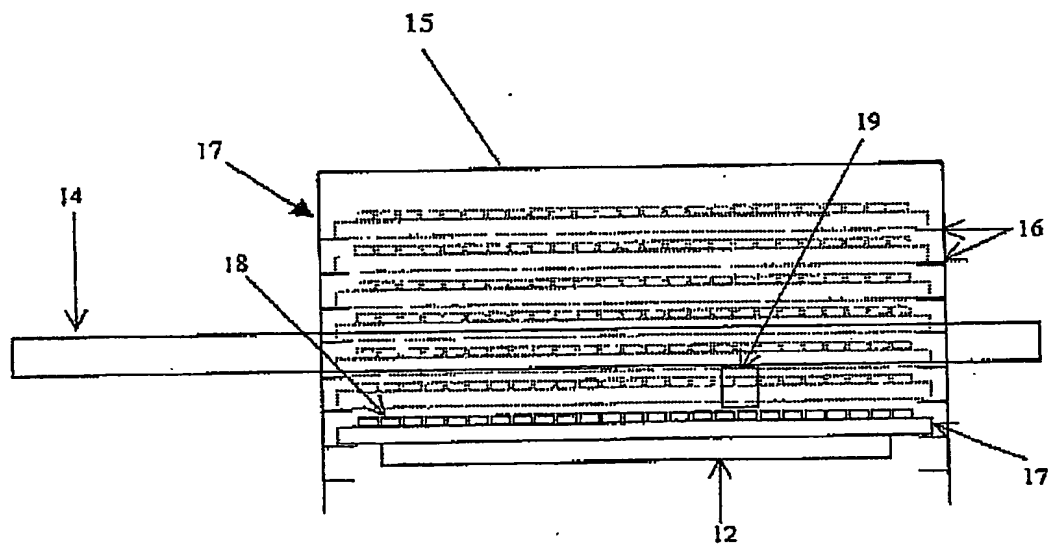
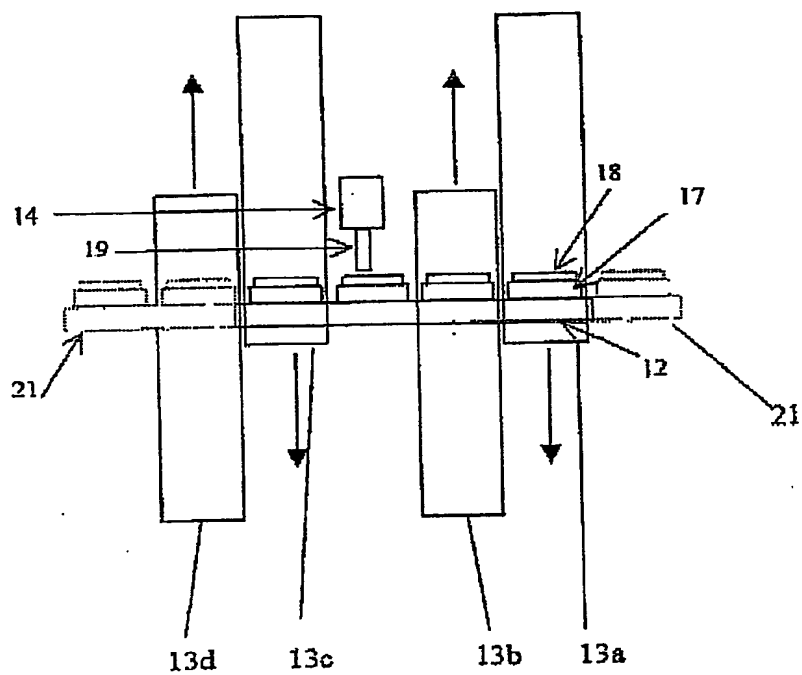


Figure 2



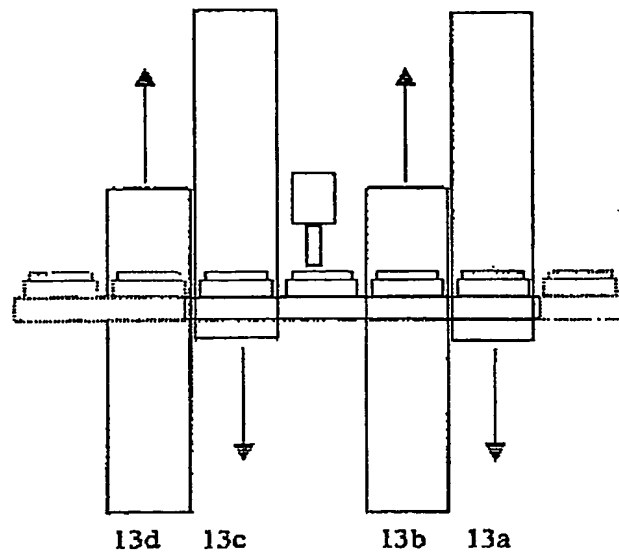
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Figure 3



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Figure 4



R1			-	-	-	Load		
R2				-	-	Load	-	-
R3	-	-	-	Print				
R4		-	Load	Print	Unload			
R5			Load	Print	Unload	Load		
R6				Print	-	Load	-	
R7	-	Unload	-	Print				
R8		Unload	Load	Print	Unload			
R9			Load	Print	Unload	-		
R10				Print	-	-	-	
R11	-	Unload	-	-				
R12		Unload	-	-	-			

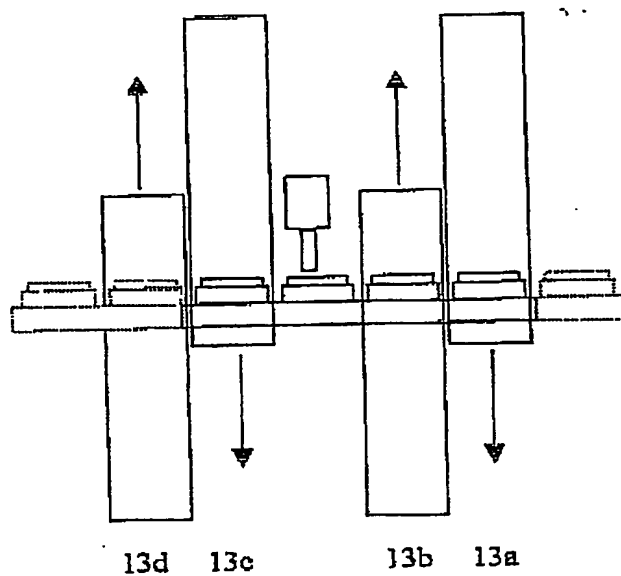
Startup sequence

Central sequence

End sequence

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Figure 5



R1			-	-	Load	-	Startup sequence
R2	-	Load	Print	-			
R3		Load	Print	Unload	Load		Central sequence
R4			Print	-	Load	-	
R5	-	Unload	-	Print			
R6		Unload	Load	Print	Unload		
R7		-	Print	Unload	-		End sequence
R8	-	Unload	-	-			



PCT Application  
**GB0304166**

